Evaluation of Ozone Injury
On Vegetation in the
Moosehorn National Wildlife Refuge
Maine

2002 Observations

Submitted to

The U.S. Fish and Wildlife Service
Air Quality Branch
Denver, CO

Donald D. Davis, Ph.D.

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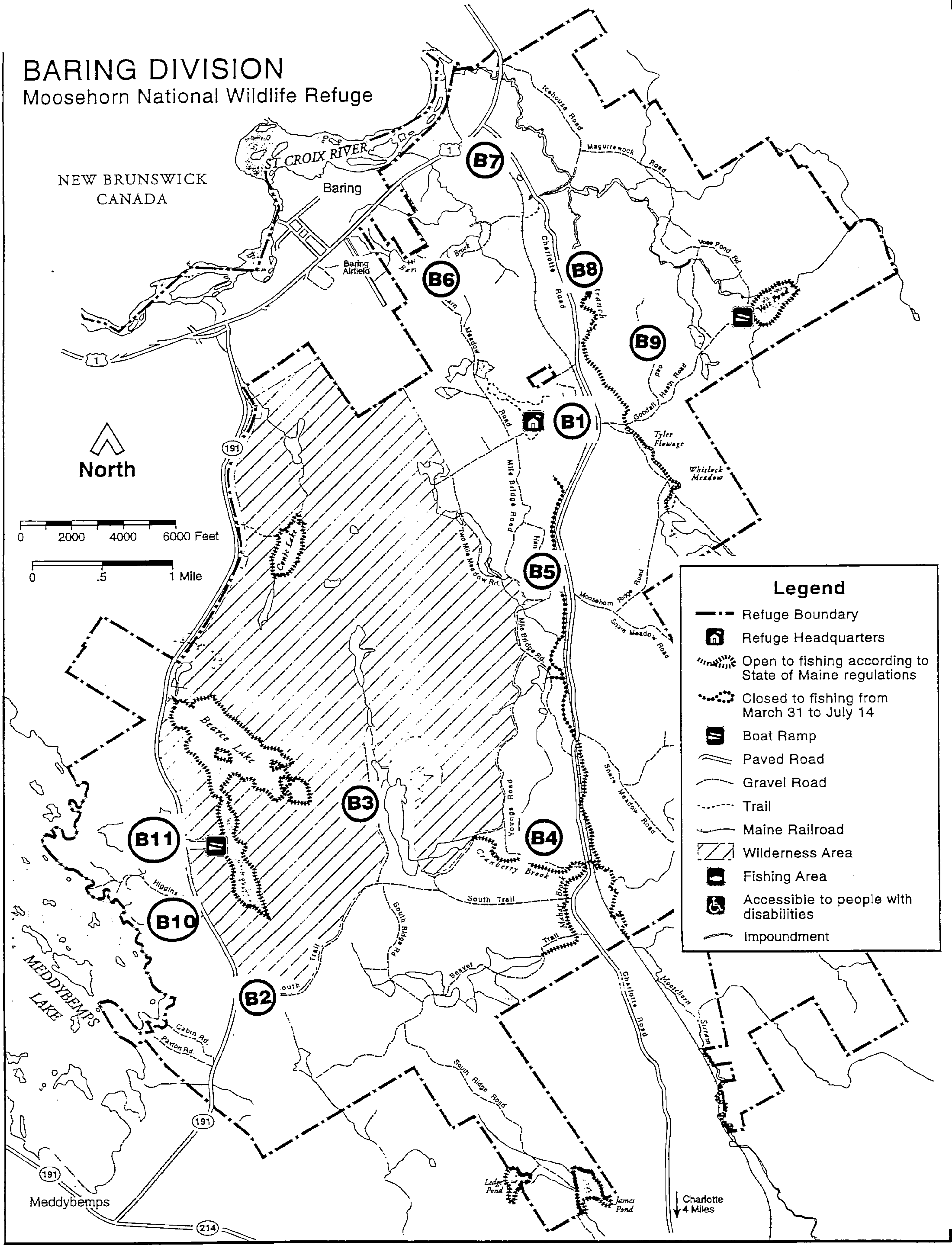

BARING DIVISION
Moosehorn National Wildlife Refuge
NEW BRUNSWICK
CANADA
ST CROIX RIVER
Baring
Baring Airfield
North
0 2000 4000 6000 Feet
0 .5 1 Mile
B1
B2
B3
B4
B5
B6
B7
B8
B9
B10
B11
Icehouse Road
Magurrewock Road
Charlotte Road
Vose Pond Rd
Goodall Heath Road
Tyler Flowage
Whitlock Meadow
Meadow Road
Mile Bridge Road
Two Mile Meadow Rd.
Moosehorn Ridge Road
Snare Meadow Road
Conic Lake
Bearce Lake
Youngs Road
Cranberry Brook
South Trail
South Ridge Rd
Higgins
Beaver
Moosehorn Stream
MEDDYBEMPS LAKE
Cabin Rd
Paxton Rd
South Ridge Road
Ledge Pond
James Pond
Charlotte 4 Miles
Meddybemps
Legend
Refuge Boundary
Refuge Headquarters
Open to fishing according to State of Maine regulations
Closed to fishing from March 31 to July 14
Boat Ramp
Paved Road
Gravel Road
Trail
Maine Railroad
Wilderness Area
Fishing Area
Accessible to people with disabilities
Impoundment

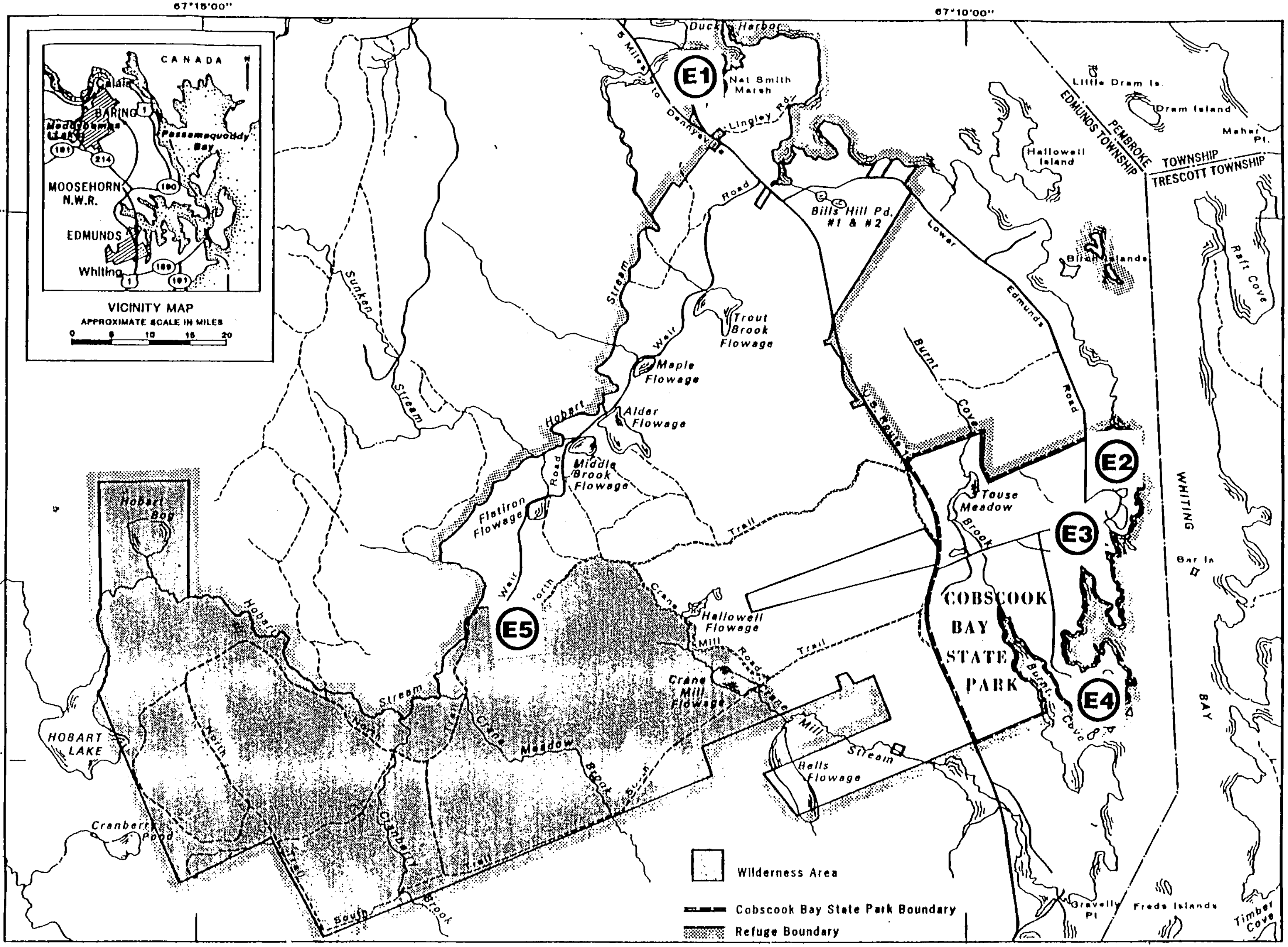
MOOSEHORN NATIONAL WILDLIFE REFUGE

WASHINGTON COUNTY, MAINE

EDMUNDS UNIT

UNITED STATES
DEPARTMENT OF THE INTERIOR

UNITED STATES
FISH AND WILDLIFE SERVICE



COMPILED IN THE DIVISION OF REALTY
FROM SURVEYS BY U S G S and U S F A W S

Diagnosis of Air Pollution Injury on Plants

Although many gaseous air pollutants are emitted into the atmosphere, only certain ones are phytotoxic and induce characteristic leaf symptoms that are useful during field surveys. The most important of these gaseous, phytotoxic air pollutants are ozone, sulfur dioxide, and fluorides. These pollutants are taken into the plant leaf, along with the normal constituents of the air, through the stomata. Once inside the leaf, the pollutant or its breakdown products react with cellular components, mainly cellular membranes, causing injury or death of tissues.

The resulting macroscopic symptoms, which are visible on the leaf surface, are classified as chronic or acute depending upon the severity of injury. Chronic symptoms imply tissue injury, whereas acute injury signifies tissue death. Chronic symptoms on foliage usually result from exposure of a plant to low levels of pollution for a long time, or occur when a plant is somewhat resistant to a pollutant. Visible ozone injury is usually considered to be chronic injury. Acute injury is observed following a short-term, high concentration of pollution, or occurs when a plant is in a very sensitive condition. Sulfur dioxide injury as observed in the field is often acute. Fluoride injury may be either.

Macroscopic leaf injury caused by air pollutants often represents an intermediate step between initial physiological events and decreases in productivity. Decreases in productivity (Pye 1988) may result in ecological changes, such as reduced diversity (Rosenberg et al. 1979). Visible leaf symptoms induced by phytotoxic pollutants serve as important diagnostic tools that allow observers to identify specific air pollutants as causal agents of vegetation damage (Davis 1984; Skelly et al. 1987, Skelly 2000). This knowledge can be used in the air pollution emissions permitting process for siting new industries (i.e. Prevention of Significant Deterioration Program), assessment of the secondary air quality standards, assessing the presence of air pollution injury in Class I areas, and in litigation involving air pollution injury.

Although ozone was the air pollutant of concern in this survey, it should be recognized that phytotoxic levels of primary pollutants such as sulfur dioxide and fluorides might occur near industrial sources. Likewise, trace elements including metals may be found in excessive levels in vegetation growing in areas downwind from industrial or urban sources (Davis et al. 1984, Davis et al. 2001). Toxic elements such as arsenic, mercury (Davis 2002), and lead may be especially important in areas being managed for wildlife. Although such compounds are of more interest in mammalian and avian toxicity as compared to phytotoxicity, vegetation may sorb such contaminants and become part of the contaminated food chain. However, the presence of excessive elements such as metals, as well as organic biohazards such as dioxins and furans, is determined with laboratory analysis of foliage, not with surveys dealing with macroscopic foliar injury.

Ozone

Ozone is probably the most important and widespread phytotoxic air pollutant in the United States, and is the air pollutant most likely to have an easily recognizable impact on vegetation within a NWR. Background levels of ozone exist naturally in the lower atmosphere, possibly originating from vertical downdrafts of ozone from the stratosphere or from lightning, but more likely from chemical reactions of naturally occurring precursors.

However, the major sources of precursors leading to phytotoxic levels of ozone originate from urban areas. In those areas, hydrocarbons and oxides of nitrogen are emitted into the atmosphere from various sources, the most important being automobile exhaust. These compounds undergo photochemical reactions in the presence of sunlight forming photochemical smog, of which ozone is a major component. Ozone, or its precursors may travel downwind for hundreds of miles during long-range transport, as influenced by wind direction and movement of weather fronts. Thus, ozone impinging on refuges may originate in urban areas many miles upwind from the refuge. Concentrations of ozone are often greater in rural areas downwind from urban areas, as compared to within the urban area itself, due to the presence of reactive pollutants in the urban air that scavenge the ozone.

There are certain bioindicator plants in the East that are very sensitive to ozone and exhibit characteristic symptoms when exposed to ozone (Anderson et al. 1989, Davis and Coppolino 1976, Davis and Skelly 1992, Davis et al. 1981, Davis and Wilhour 1976, and Jensen and Dochinger 1989). The principal investigator in this survey routinely uses the following broad-leaved bioindicator species for evaluating ozone injury: black cherry (Prunus serotina), common elder (Sambucus canadensis), common milkweed (Asclepias syriaca), grape (Vitis spp), white ash (Fraxinus americana), and yellow-poplar (Liriodendron tulipifera). The investigator also uses, but less commonly, Virginia creeper (Parthenocissus quinquefolia) and Viburnum spp. Many of these ozone-sensitive species occur in our refuges in eastern United States. August and early September are the best times to survey for ozone-induced injury in the Northeast (Davis and Skelly 1992).

On broadleaved bioindicators, ozone-induced symptoms usually appear as small 1 - 2 mm diameter "stipples" of pigmented, black or reddish-purple tissue on the adaxial surface of mature leaves (see Skelly 2000, Skelly et al. 1987). The pigmented tissue is usually restricted by the veinlets. Immature leaves seldom exhibit symptoms, whereas premature defoliation of mature leaves may occur on sensitive species. To the casual observer, these symptoms are similar to those induced by other stresses (e.g., nutrient deficiency, fall coloration, heat stress, as well as certain insects, and diseases). However, the pigmented, adaxial stipple on plants of known ozone-sensitivity (i.e., black cherry or grape) is a reliable diagnostic symptom that can be used to evaluate ozone injury.

On eastern conifers, the most reliable symptom (current-year needles only) induced by ozone is a chlorotic mottle, which consists of small patches of chlorotic tissue interspersed within the green, healthy needle tissue. The mottle usually has a "soft edge" (as opposed to a sharply defined edge) to the individual mottled areas. An extremely sensitive plant may exhibit needle tip browning. However, this latter symptom is caused by many stresses and not a reliable diagnostic symptom. Conifer needles older than current-growing season needles are not useful as monitors, since over-wintering and multi-year insect injuries may produce needle symptoms similar to that caused by ozone. Ozone injury to monocots, such as grasses (i.e., Spartina sp.), is also very difficult to diagnose in the field, as there are many causal agents that can result in tipburn and chlorotic mottle on grasses.

Description of Refuge

(Adapted from Refuge Brochures)

The Moosehorn Refuge is a highly glaciated expanse of rolling hills, large ledge outcrops, streams, lakes, bogs, and marshes. The Edmunds Unit has several miles of rocky shoreline where 24-foot tidal fluctuations are a daily occurrence. Approximately 2,780 acres of the Edmunds Unit and 4,680 acres of the Baring Unit were set aside as Wilderness Areas by Congress. As part of the National Wilderness Preservation System these areas are granted special protection that will insure the preservation of their wilderness characteristics.

Vegetation

The area is rich with history from the logging boom days. In the 1800's horses hauled millions of cords of wood to the shores of the St. Croix River where spring floods carried the logs to Calais mills. Logs were shipped from Calais to world markets by schooner and steamship. However, in the early 1900's, the forest industry began to mechanize and the world market for timber declined. The numerous farms that once were necessary to feed man and beast were abandoned and the forest gradually reclaimed the farmland. A diverse forest of aspen, maple, birch, spruce, and fir currently dominates the landscape and scattered stands of majestic white pine are common.

The refuge is located in terrain that consists of rolling hills with large rock outcrops and scattered boulders. The dominant vegetation in the vicinity of both Units is uneven-aged, second-growth northern conifer-hardwood forest, with some areas in pure spruce-fir. Much of the area was logged and cleared in the 1800s and early 1900s, and several fires have burned over large portions of the area, the last in 1933. Numerous stream valleys, beaver flowages, ericaceous bogs, marshes, and forest/shrub-dominated wetlands occur throughout the area. The deciduous component of the forest includes mixed stands of quaking and bigtooth aspen (Populus tremuloides, P. grandidentata), paper and gray birch (Betula papyrifera, B. populifolia), red maple (Acer rubrum), American beech (Fagus grandifolia), and black cherry (Prunus serotina).

Common understory species include winterberry (Gaultheria procumbens), bracken fern (Pteridium aquilinum), sedges (Carex spp.), and bunchberry (Cornus canadensis). Mixed hardwood-conifer stands occur in many areas, with the generally more shade-tolerant conifers gradually replacing the earlier successional hardwoods, The coniferous component is dominated by mixed and pure stands of spruce (Picea spp.) and balsam fir (Abies balsamea). Scattered old-growth white pine (Pinus strobus) are an indication of the original climax forest that was present before the lumbering and fires of the last century. Pure stands of alder (Alnus rugosa) are abundant in reverting farmland and wet areas along the margins of streams and beaver flowages. Several blueberry (Vaccinium spp.) fields, meadows, and pastures are maintained as permanent forest openings. In 1976, a long-term management plan was implemented on the refuge to increase the diversity of forest habitat by altering age and species composition, utilizing specific timing of cutting.

Wetlands present in the area include beaver ponds and meadows, marsh, shrub, and forested wetlands of various types, and open-water in the form of streams, ponds and lakes. Beaver meadows in the area are dominated by blue-joint grass (Calamagrostis canadensis) and sedges, with wetter sections and pond fringes supporting marsh plants such as rushes (Juncus spp.), cattail (Typha latifolia), bulrushes (Scirpus spp.), and other non-persistent emergents and aquatic species. Alder and willow (Salix spp.) are common wetland shrubs, and leatherleaf (Chamaedaphne calyculata), sweet gale (Myria gale), and sphagnum moss (Sphagnum spp.) are dominant bog species. Forested wetlands are dominated by stunted spruce, some white cedar (Thuja occidentalis), red maple, sphagnum, cinnamon fern (Osmunda cinnamomea), and some larch (Larix laricina).

The majority of the Cobscook Bay area is in second growth spruce-fir-pine forest, mixed with some maple, birch, and aspen. There is also some open land, and previously open land in regrowth stages. The waters adjoining the bay are tidal with fluctuations of up to 24 feet, creating extensive areas of intertidal mudflats in several coves. The tidal range and southern exposures create important ice-free and protected wintering habitat conditions for waterfowl and bald eagles. Many large, old-growth pines are present on uplands adjacent to the shoreline, providing nesting and roosting trees for eagles and other raptors.

A listing of Moosehorn NWR vegetation, as supplied by refuge personnel, is presented in the Appendix.

Wildlife

Moosehorn Refuge is unique among the country's National Wildlife Refuges. Here the American woodcock is intensely studied and managed. This reclusive bird dwells in the alder cover by day and refuge clearings at night. Unfortunately, the Eastern Flyway woodcock population has declined steadily over the past two decades. Research and management programs at Moosehorn have provided valuable information that is being used to stem this decline.

The endangered bald eagle frequents both units of the refuge. In recent years as many as three pairs of eagles have nested at Moosehorn. Eagles are frequently sighted in the area around the Magurrewock Marshes near U.S. Route 1 on the Baring Unit and around the tidal waters of Dennys Bay on the Edmunds Unit.

The woodlands of Moosehorn also abound with many other species. Black bears are abundant and can often be seen along refuge roads in the spring, in the blueberry fields in August, and foraging for apples in the fall. White-tailed deer and an occasional moose feed in the many clearings scattered throughout the refuge. In mid-May a flush of migrating warbles fills the woodlands with song.

The refuge also serves as an important breeding area and migration stop for a variety of waterfowl and other waterbirds. Black ducks, wood ducks, ring-necked ducks, Canada geese, and loons can be seen on the more than 50 lakes, marshes, and flowages scattered throughout the refuge. In mid-May the Magurrewock Marsh, which borders U. S. Route 1 on the Baring Unit, abounds with goose and duck broods. Bald eagle sightings also are a common occurrence. Ospreys nest in several of the refuge marshes and the ardent observer can often find river otters frolicking among the cattails. Moosehorn plays an important role in protecting the fragile and diminishing wetland resources of the Atlantic Flyway.

Management

Woodcock, ruffed grouse, moose, deer, and a variety of songbirds thrive only in a young forest. In the past, wildfires periodically rejuvenated the forest. However, wildfire is a rare event today. Forest management programs on the refuge serve to take the place of fire. Small clearcuts scattered throughout the forest provide openings and young brushy growth that serve as food and cover for many wildlife species. This management has resulted in dramatic increases in many species including woodcock, grouse, bear, and moose. Timber harvesting also provides local employment, and a percentage of receipts from sales is returned to local communities.

Wetlands management on the refuge has greatly increased waterfowl numbers. Water control structures on the refuge's marshes and ponds allow managers to maintain stable water levels during the breeding season. Water level control also improves the growth of plants that provide food and cover and allows the marshes to be emptied periodically for rejuvenation. The creation of channels, potholes, and islands, as well as shoreline improvement, also has increased waterfowl production and encouraged nesting.

METHODS

General Survey Areas

It had been predetermined that survey sites had to occur in open-areas (such as those occurring along roads or trails, or in fields) where ozone-sensitive plant species were found in sunlight and exposed to unrestricted air movement (Anderson et al. 1989; USDA Forest Service, 1990). Immediately prior to the initial 1998 survey, the investigator met with refuge personnel to view maps of the refuge. Ensuing discussions greatly aided selection of preliminary survey areas on the maps. Based on these initial discussions, tentative survey areas were selected throughout the refuge. These areas were visited in the field during the 1998, 1999, and 2000 surveys, and their suitability for survey determined as plants were evaluated. These general areas, with slight modifications, were used in the 2002 survey.

Preliminary Selection of Bioindicator Species

An extensive list of refuge flora was furnished to the investigator by the U.S. Fish and Wildlife Service (Appendix). Prior to the initial (1998) survey, an initial selection of potential bioindicators that might exhibit ozone injury in the survey area had been selected from this list. Plant species or genera on the list that were tentatively selected as bioindicators included: ash (Fraxinus sp.), aster (Aster sp.), black cherry (Prunus serotina), blackberry (Rubus sp.), choke cherry (Prunus virginiana), common milkweed (Asclepias syriaca), elderberry (Sambucus canadensis), mountain ash (Sorbus americana), pin cherry (Prunus pensylvanica), poison-ivy (Rhus radicans = Toxicodendron radicans), serviceberry (Amelanchier laevis), sumac (Rhus sp.), trembling aspen (Populus tremuloides) and viburnum (Viburnum sp.).

Of course, many of the species listed grow in scattered localities through the NWR, and may not be present at designated survey areas; they may only be found with the help of local botanists. Also, most plant species growing in the more wet areas of the refuge have not been studied with regard to ozone-induced macroscopic symptoms. That is, the ozone-sensitivity of wetland species, as determined by controlled exposures of ozone, is generally unknown.

Air Quality

Ozone monitoring data complement the visual injury surveys. In general, more ozone-induced stipple is likely to occur in years with greater ozone concentrations. However, more consistent and long-term monitoring datasets are needed to further understand the relationship between foliar symptoms, ambient ozone, and environmental conditions (e.g. droughts) in our parks and refuges.

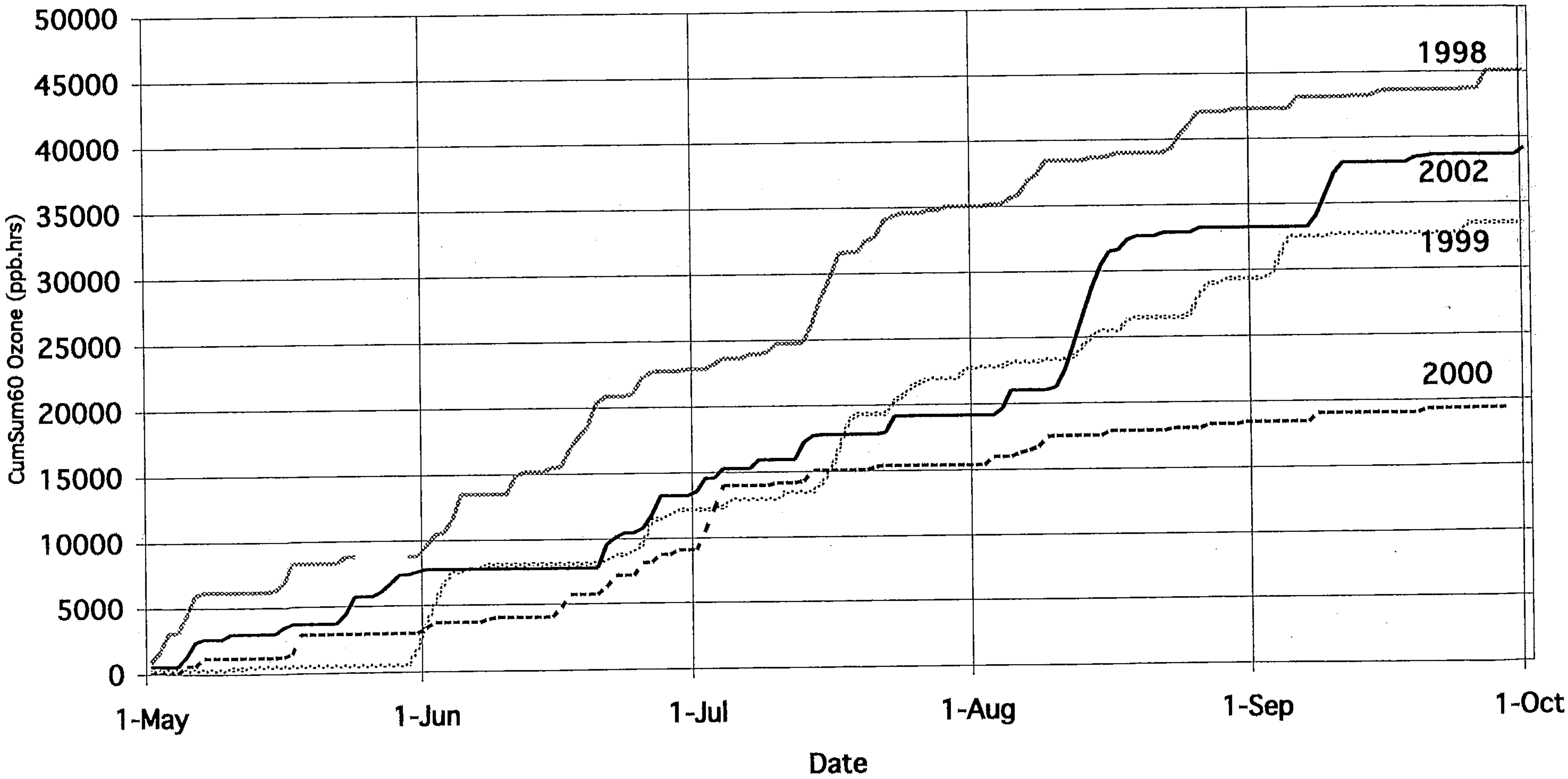
The nearest ozone monitor with the complete ozone datasets is located in the Acadia National Park at Cadillac Mountain (EPA AIRS site #23-009-0102), approximately 70 miles southwest of the Moosehorn NWR. Ambient ozone levels in this report are expressed as "cumsum60", the cumulative sum of all hourly ozone concentrations equaling or exceeding 60 ppb. In other studies, we have found that this ozone statistic correlates fairly well with plant damage. During the 4 years of survey (1998-2000, 2002), ozone levels monitored at Cadillac Mountain were variable, being greatest in 1998, intermediate in 1999 and 2002, and least in 2000 (Figure 2). By late summer, the cumsum60 ozone levels in 1998 were clearly at phytotoxic levels; the 1999 and 2002 levels were considered somewhat phytotoxic. In 2000, the ozone levels were very low and probably just at the threshold limits for plant injury to occur

The maximum cumsum60 values during the years of survey were greatest in 1998, reaching approximately 45,000 ppb-hrs. For comparison to a refuge with extreme ozone concentrations, the ozone levels at the Edwin B. Forsythe NWR near Brigantine, New Jersey, reached about 80,000 ppb-hrs in 1991 (a very high ozone year), and are routinely greater than 40,000 ppb-hrs by the summer's end. During 1999, ozone levels in the Mingo NWR in Missouri likewise reached 80,000 ppb-hrs by early fall.

Assuming that the ozone levels monitored at Cadillac Mountain (70 miles away) are similar to those occurring at the Moosehorn NWR, ozone injury is likely to occur most years on ozone-sensitive species of vegetation within the refuge. However, to my knowledge, there have been no recorded surveys prior to 1998 to document whether or not ozone injury has occurred on refuge vegetation.

Figure 2. Cumulative sum of all hourly ozone concentrations equaling or exceeding 60 ppb (cumSUM60) monitored at Acadia National Park, Cadillac Mountain, Maine (EPA AIRS Site # 23-009-0102) during 1998-2002; units are ppb-hrs. This monitoring site is located approximately 70 miles southwest of the Moosehorn refuge.

CumSum60 Ozone Levels
Moosehorn NWR
(EPA AIRS Site # 23-009-0102)



Surveys Dates and Locations

The Moosehorn National Wildlife Refuge was surveyed twice in 1998, on July 29-August 2 and August 25-28. In 1999 the refuge was surveyed once, during July 22-25. It was fortunate that the earlier date was chosen in 1999, because a widespread drought occurred in the East during late summer. During 2000, the Moosehorn NWR was surveyed during August 21-23. The refuge was not surveyed in 2001. In 2002 the refuge was surveyed during August 29-September 2. Based on the 4 years of surveys, the best time to survey this refuge is in mid- to late-August. An extreme drought occurred in the Northeast prior to and during the 2002 survey.

As described earlier, the tentative location of survey areas was based on discussions with refuge personnel and examination of maps at the refuge headquarters prior to the initial (1998) survey. These areas were then visited on-site during the 1998, 1999, and 2000 surveys, and 16 approximate locations were selected. These sites were considered suitable for ozone injury surveys based on openness, accessibility, and presence of bioindicators (Figure 1). All 16 sites were visited in 2002, but data was not taken at all sites. As in 2002, an additional area ("The Woodcock Trail") adjacent to plot B1 was surveyed. In addition to these specific areas, foliage of vegetation was observed as the investigator traveled from site to site.

Severity Rating

Each broadleaved plant evaluated for ambient ozone injury had to have foliage within reach; that is, trees were not climbed nor were pole-pruners used. The ForestHealth Expert System had been used to train the investigator in estimating the amount of stipple on a leaf. For broadleaved tree species, the percentage of ozone injury was estimated on the oldest leaf on each of four branches, and the average value recorded. Then, the next oldest leaf was evaluated, and so on, until the five oldest leaves had been rated. For each herbaceous plant, each of the five (if present) oldest (basal) leaves of the plant was examined and the average percent stipple recorded. Each of the oldest five leaves on the current woody growth (canes) of vines was rated and the average percent stipple recorded. On all species, only adaxial leaf surfaces were evaluated. Symptom severity on the adaxial surface of each leaf evaluated was estimated by assigning severity classes, based on the percentage of surface injured, of 0, 5, 10, 20, 40, 60, 80, 90, 95 and 100 %. Photographs (slides) were taken and originals sent to the FWS Air Quality Branch in Denver.

RESULTS AND DISCUSSION

Final Selection of Bioindicator Species

Following the initial evaluation of the vegetation lists in early summer 1998, a more complete selection of bioindicator species or genera was made in the field during 1998. For example, during the first 1998 visit to the refuge, it was immediately obvious that spreading dogbane (Apocynum androsaemifolium) was exhibiting adaxial stipple, typical of that caused by ozone, at several sites. Therefore, dogbane was added to the bioindicator list, which then consisted of ash (mainly white ash), black cherry, blackberry, choke cherry, pin cherry, serviceberry, and trembling aspen as potential bioindicator species. These were among the most common ozone-sensitive species in the refuge, and usually occurred in open areas. Not all species/genera listed were present at all sites. In addition, most wetland plant species of the Moosehorn refuge have not been carefully studied with regard to ozone-induced macroscopic symptoms. That is, the ozone-sensitivity of wetland plants as determined by controlled exposures of ozone is generally unknown. Of course, spring ephemerals were not evaluated at this late date.

During the 1998 and 1999 field surveys, the bioindicator list was amended to also include sand cherry (Prunus pumila), raspberry (Rubus idaeus), and sarsaparilla (Aralia nudicaulis). The latter two species, along with blackberry, were selected as indicators for SO_2 injury. However, since there were no apparent point sources of SO_2, emphasis was placed on the ozone-sensitive bioindicators. The list, as mainly compiled during 1998-1999 was used during the 2000 and 2002 surveys.

Foliar Symptoms

In spite of the fairly high ozone levels recorded in 2002 (Figure 2), only light ozone injury was observed within the Baring and Edmunds Units during the 2002 visit (August 29-September 2). This was possibly related to the severe drought that was widespread along the East Coast in 2002. Such drought induces stomatal closure, precluding uptake of ozone and reducing subsequent leaf injury due to ozone.

Baring Unit

Site B1 (Refuge Headquarters and "Woodcock Trail"). Vegetation was examined in the large, open fields along the entrance road leading to the refuge headquarters and along the Woodcock Trail loop (Figure 1, Location B1). There were several bioindicator "species" present in these large openings and along the trail at this excellent survey site.

Ozone injury was present on 44 of 134 (32.8%) spreading dogbane plants examined at this site in 2002 (Table 1). The severity of ozone injury on the symptomatic leaves usually involved less than 5-10% of the adaxial leaf area, but at times involved up to 60% of the leaf surface (Table 2). On occasional plants, the injury was severe, resulting in black, bifacial tissue collapse. In 1998 and 1999 the ozone injury on dogbane at this site had been restricted to older paired leaves on the primary stems, and did not occur on the pairs of leaves further out the secondary shoots. (Secondary shoots arise from the axils of the pairs of primary stem leaves). However, in both 2000 and 2002 the ozone injury also occurred on the leaves further out the stem in addition to the two older paired leaves. Occasional dogbane plants showed premature defoliation. Ozone injury was not present on dogbanes growing in shaded areas.

Near the upper edge of one field, brush had been mowed previously and fast-growing, succulent aspen root sprouts (root suckers) were present. It was difficult to distinguish between very small bigtooth and quaking aspen sprouts. Ozone injury was present on 27 of 69 (39.1%) of the aspen sprouts at this site in 2002 (Table 1). In 1998 this site had not been mowed and there were no aspen sprouts present. However, in 1999, 2000, and 2002, ozone injury occurred on these fast-growing sprouts, but did not occur on adjacent, larger, aspen trees or older, aspen saplings. On the sprouts, the injury was most severe on the oldest and lowest leaves at the base of the plant. The severity of the ozone injury on the lower leaves was likely due to a combination of leaf age and the high humidity of the lower, grass environment. However, diagnosis of the ozone-induced stipple was confounded by the presence of Septoria leafspot on the lowest aspen leaves.

Along the Woodcock Trail, classic ozone-induced stipple was observed on 2 of 12 (16.7%) of plants tentatively identified as Viburnum lentago. The investigator has observed ozone stipple on various species of Viburnum in other surveys, and considers the genus Viburnum to be an under-used bioindicator with excellent potential, perhaps similar in utility to the genus Sambucus. This species of Viburnum could prove to be a valuable addition to the bioindicators already used for detecting ozone injury in the refuge. Viburnum species generally exhibit more of a classic stipple, as compared to ash or pin cherry, and do not defoliate as readily as spreading dogbane. In the future, consideration should be given to more thorough ozone-injury survey using this species of Viburnum. Refuge, or local, botanists should identify the Viburnum species present in the refuge.

Ozone injury was not observed on blackberry, black cherry, choke cherry, sand cherry, or mountain-ash. Although choke cherry was evaluated, the investigator considers this species to be tolerant to ambient ozone and it should not be evaluated in the future. When the aspen species was distinguishable, trembling aspen appeared to be more sensitive to ozone than was bigtooth aspen. There was a slight reddening, which may or may not have been related to ozone injury, on blackberry and a few other species. During the 2002 survey, leaf injury resembling that caused by SO_2 was not observed at this or any other site within the Moosehorn NWR.

Stresses other than ozone injury were noted at this site. Dogbane leaves were beginning to become chlorotic (partially due to ozone?) and had a moderate level of leaf blotch. Dogbane plants also had a higher infestation of caterpillar webs than in past years, and leaves suffered from more leaf chewing than in past years. Black cherry foliage commonly had Cercospora-type leafspots. Pin cherry leaves had shotholes, in addition to leafspots. Aspen had small, dark Septoria-type leafspots. Blackberry leaves exhibited some reddening.

Table 1. Summary of observations made during the September 2002 survey at the Moosehorn National Wildlife Refuge. Numbers in table refer to number of plants with ozone-induced injury as compared to the total number of plants evaluated for that species, and expressed as percentages. Comparison is made with the 1998 (August), 1999 (September), and 2000 (September) results.

Date/Site	Ash	Aspen	Blackberry	Cherry Black	Cherry Choke	Cherry Pin	Cherry Sand	Dogbane Spreading	Mtn-Ash	Raspberry	Sarsaparilla	Serviceberry	Viburnum
August 98 Total	1/54	10/126	0/53	0/55	0/30	28/108		7/77					
Aug 98%	1.8%	7.9%	0.0%	0.0%	0.0%	25.9%		9.0%					
1999 Total	2/77	9/396	0/330	5/111	0/260	4/196	0/40	10/178	0/10	0/230	0/10	1/49	
1999%	2.6%	2.3%	0.0%	4.5%	0.0%	2.0%	0.0%	5.6%	0.0%	0.0%	0.0%	2.0%	
2000 Total	6/150	12/154	0/200	0/86	0/60	13/176	0/50	24/120	0/10	0/180	0/30	1/40	2/10
2000%	4.0%	7.8%	0.0%	0.0%	0.0%	7.4%	0.0%	20.0%	0.0%	0.0%	0.0%	2.5%	20.0%
2002													
Baring Unit													
B1		27/69	0/50	0/10	0/20	0/10		44/134					2/12
B2	2/57												
B3	1/20	0/20											
B4		0/20		0/33		0/36		0/20					
B5		0/50		0/7		0/10		0/20					
B6													
B7													
B8	0/8		0/20		0/10					0/20		0/3	
B9	1/12	0/50	0/50							0/50	0/30	0/10	
B10													
B11	0/20												
Edmunds Unit													
E1		0/20	0/20	0/10		0/10	0/100	0/40		0/20		0/30	
E2			0/40			3/50			0/10	0/20	0/50		
E3		3/30	0/100		0/20	0/2		0/5		0/100		0/6	
E4		0/100				3/60							
E5		0/50				0/50				0/50			
E6		0/100						1/75					
E7		0/50				0/15		0/50					
2002 Total	4/117	30/559	0/280	0/60	0/50	6/243	0/100	45/344	0/10	0/260	0/80	0/49	2/12
2002%	3.4%	5.4%	0.0%	0.0%	0.0%	2.5%	0.0%	13.1%	0.0%	0.0%	0.0%	0.0%	16.7%

Table 2. Severity of ozone-induced injury on leaves of symptomatic leaves of 10 aspen and 10 spreading dogbane plants at Site B1.

		Leaf No.				
Species	Plant No.	1*	2	3	4	5
Aspen	1	5**	0	0	0	0
	2	60	60	10	10	10
	3	40	40	40	40	20
	4	20	20	40	20	20
	5	10	20	20	10	10
	6	40	10	0	0	0
	7	20	20	10	10	0
	8	10	10	5	5	5
	9	40	10	5	5	5
	10	40	10	5	5	5
Dogbane						
	1	10	10	0	0	0
	2	0	5	10	***	***
	3	5	5	5	5	5
	4	5	20	20	10	5
	5	5	5	5	5	5
	6	5	5	5	0	0
	7	40	40	0	0	0
	8	60	60	20	10	10
	9	5	5	5	0	0
	10	0	5	0	0	0

*Oldest leaf of the 5 leaves evaluated.

**Severity values = 0, 5, 10, 20, 40, 60, 80, 90, 95, and 100% of leaf tissue injured.

***Leaves missing

(Baring Unit, Cont'd.)

Sites B2-B11 (see Table 1). At site B2 (the western end of South Trail Road) 2 of 57 (3.5%) of the ash seedlings and saplings examined showed classic ozone injury in 2002. The area appeared to be very droughty.

At site B3 (Cranberry Lake Inlet) 1 of 20 (5.0%) ash plants, but none of the 20 aspens, exhibited ozone injury. Insect injury was common on birch foliage, as were vein galls on ash leaves.

Aspen, black cherry, spreading dogbane, and pin cherry plants at site B4 (Cranberry Brook) likewise showed a lack of ozone injury. Dogbane leaves at this site were quite green, and the plants were in flower. Black cherry trees and saplings had black knot infections of branches and twigs, as well as Cercospora-type leafspots. Pin cherry leaves commonly exhibited shotholes. Sweetfern foliage was turning red. Fruit was ripe on both blueberries and blackberries. Here and elsewhere, there was little useful foliage on the (2-year old) fruiting canes of the blackberry plants, as it had discolored and was senescing.

At site B5 (Hanson Soil Pit Road), pin cherry showed no ozone injury, and many of the aspen sprouts were stressed by a fungal leaf and shoot blight, likely caused by the fungus <u>Venturia</u>. Many aspen plants were not evaluated at site B5 because of this confounding factor. However, several adjacent clearcuts were found that had fewer fungal diseases on the aspens. In these areas, none of the 50 aspens evaluated had ozone injury, nor did black cherry, pin cherry, or spreading dogbane plants.

As in past years, few good indicator plants were found at sites B6 (Barn Meadows #2) and B7 (Powerline at the intersection of Route 1 and Charlotte Road) in 2002; these two sites have been eliminated from the survey.

Site B8 (West Branch Observation Deck) is also marginal site in terms of usefulness, but was more useful than sites B6 and B7; ozone injury was not observed on any bioindicator plants at site B8. Hawthorn foliage, on plants growing on the mound near the deck, had a dark leafspot. Sweetfern leaves were starting to turn red.

Site B9 (road to former air monitoring station) was expanded in 1999 to include Voss Pond and is now an excellent survey site. Light, marginal stipple was observed on 1 of 12 (8.3%) of the ash plants at site B9 in 2002, but not on other bioindicator species. Spreading dogbane leaves were greener in this more shaded location, as compared to plants growing in the open. However, dogbane plants still exhibited low levels of leafspots at this location. Leafspots also occurred commonly on hawthorn, black cherry, and red maple foliage at this site. Light levels of <u>Venturia</u> shoot blight occurred on aspen here and throughout the area; aspens also had small Septoria leafspots that complicated evaluation of stipple. Fruiting canes of blackberry had few useful leaves for evaluation purposes. Insect disorders were noted on many species of plants including alder, aspen, blackberry, cherries, oaks, willow, and others. The most severe insect problem noted was the severe skeletonizing of alder leaves by caterpillars. This severe infestation had been observed during past surveys.

Ozone injury was not observed on ash seedlings and saplings examined at site B11 (Bearce Flowage)

Sites B6, B7, B10 (Higgins Road) and B11 (Bearce Flowage) are considered to be marginal survey sites. However, all four sites will be maintained, and possibly revisited if the survey is conducted in future years.

Edmunds Unit

Site E1. Vegetation was examined in 2002 in and around the edges of the farm fields near the Nate Smith Marsh. In spite of the name "Marsh", most of this survey site was conducted within an old hayfield that is rather sandy and droughty. Ozone injury was not observed on aspen, blackberry, black cherry, pin cherry, sand cherry, serviceberry, or spreading dogbane. Raspberry plants had healthy leaves at this site. The trembling aspen leaves, were small, tough, and leathery – conditions not conducive for ozone injury. Occasional dogbane plants were very yellow at this site in 2002, possibly related to drought stress. Black knot disease was very severe on various Prunus species at this location. Blackberry foliage was turning red. Many of the shrubby vegetation had twig dieback, and associated wind pruning, that appeared to be related to wind-driven salt. The entire area was very droughty.

Site E2. Ozone injury was not observed on blackberry, black cherry, or mountain-ash plants near the boat launch in Cobscook State Park (Table 1). Raspberry and sarsaparilla plants also had healthy leaves at this site, but both were turning red. Blackberry foliage had moderate aphid curling and were also turning red. It has been my experience that this reddening is common in many plant species (especially Rubus) suffering from moisture stress. Ozone injury was observed on 3 of 50 (6.0%) of the pin cherries examined. As in past years, mountain-ash leaves had severe leafhopper-type injury, which confounded ozone injury evaluation on this species. Here and elsewhere in the refuge area, there was no SO_2 injury on sensitive plant species such as birch, raspberry, blackberry, or sarsaparilla.

Site E3. Bioindicators were examined in and around the edge of this very large field within the Cobscook State Park, located along the edge of Whiting Bay. Ozone injury was noted on 3 of 30 (10.0%) of the pin cherry plants examined. Foliage of blackberry and raspberry plants was turning red. Webworm infestations were light on choke cherry. Skeletonizing insects were severe on alder leaves.

Site E4. Vegetation was examined in this large field near the south end of Cobscook State Park. There was a large clump of pin cherry saplings in the field. These plants were possibly from the same seed source, or sprouts, since they were growing close together. In 2002, ozone injury was noted on 3 of 60 (5.0%) pin cherry saplings. However, these plants also very red, possibly due to the drought, making it difficult to evaluate stipple. The pin cherry leaves also exhibited shotholes and leafspots. Trembling aspen seedlings had severe leafspots and tip dieback.

Site E5. There was no ozone injury noted on any bioindicators examined near the intersection of North Trail and Weir Road. Raspberry plants were red at this location.

Site E6. This excellent site was established in 2002, near the beginning of North Trail. The site consists of a large open field containing hundreds of spreading dogbane plants and thousands of small aspens. Both the spreading dogbane and trembling aspen plants at this site had dark green, healthy leaves. Little drought injury, leafspots, or chlorosis was noted at this site. (Perhaps this location has a higher water table.) Interestingly, the site also contains a large number of lilac shrubs, which were free of ozone injury.

Site E7. This additional site was also established in 2002, and is located in a large field along Weir Road near the Flatiron Flowage pond. The large field contains many aspens and spreading dogbane plants, none of which exhibited ozone injury in 2002. However, many of the dogbane plants were quite chlorotic.

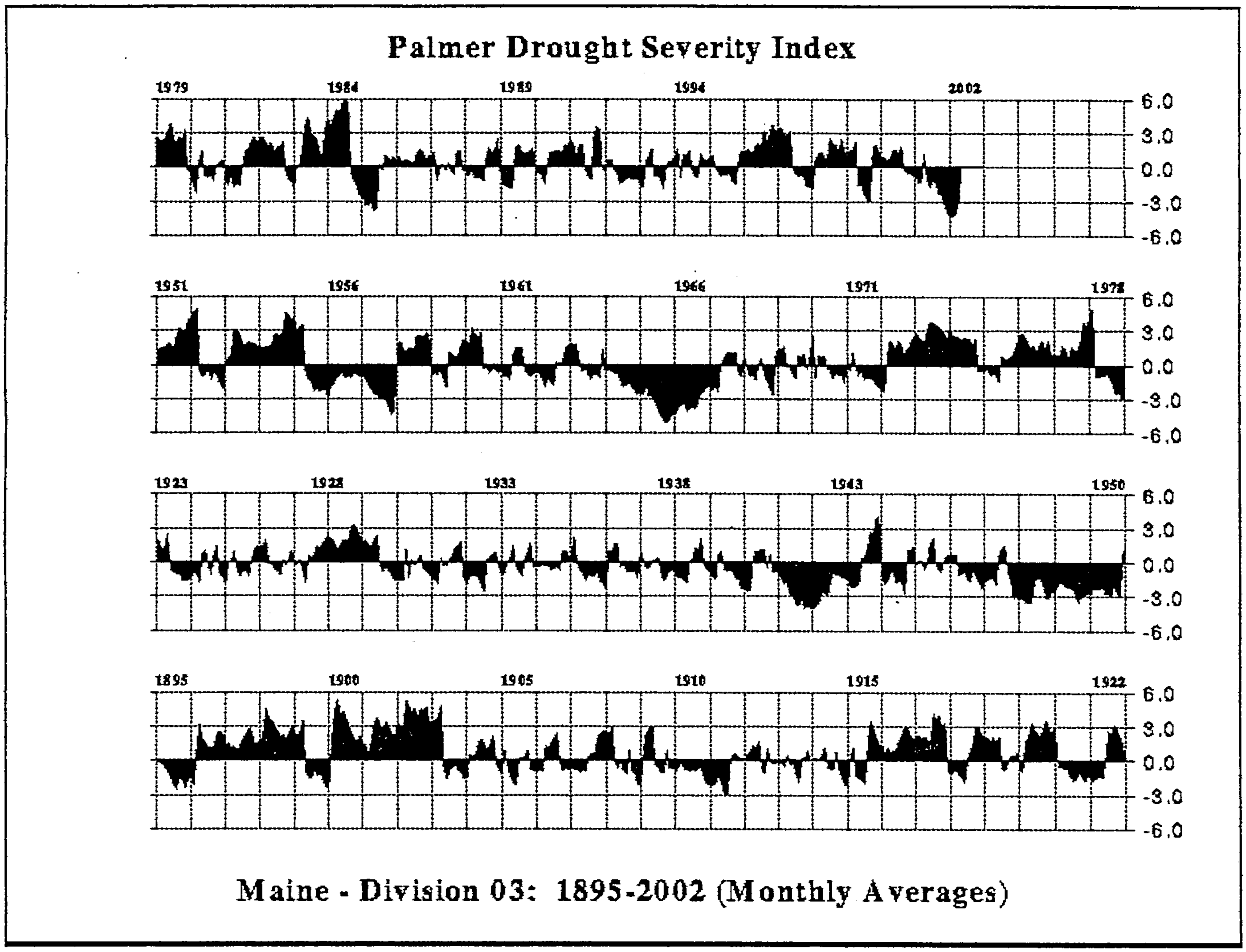


Figure 4. Palmer Drought Severity Index for coastal Maine, including Moosehorn NWR, during 1895 - 2002. Data for 2002 is only partial at time of report writing, but illustrates the very severe drought that was encompassing the East Coast in 2002. The horizontal line at "0" is considered normal moisture levels. Areas above the line represent more than adequate moisture for normal plant functioning, whereas areas below the line represent water stress. A drought severity index of -3 is considered to be a severe drought, likely reducing ozone uptake.

SUMMARY

The results of this 2002 survey revealed that ozone injury was present in low levels on vegetation within the boundaries of the Moosehorn NWR, a portion of which is a Class I air quality area. In 1998 (August), ozone-induced foliar symptoms were fairly high, and were related to the high levels of ambient ozone that year (Figure 2). The 1999 ambient ozone levels were lower than in 1998, and 1999 was a dry year. The drought symptoms as observed in 1999 were widespread, and included plant yellowing, wilting, curling and defoliation. It is very likely that the dry weather of 1999 precluded ozone uptake by plants, and reduced subsequent symptom development in that year. The ozone levels of 2000 were very low, but moisture conditions during the survey appeared adequate. There was no observed wilting of plants due to drought stress during the 2000 surveys. Thus, in spite of the low ambient ozone concentrations, ozone-induced injury did occur in the summer of 2000 within the refuge. In 2002, ambient ozone levels were fairly high, but there was a widespread and severe drought along the East Coast of the U.S. (Figure 4). Thus, the level of ozone injury on bioindicators was not as severe as it might have been without the drought. Nevertheless, this survey illustrated that ambient ozone occurs at such levels to cause ozone injury on sensitive bioindicators in Class I Wilderness areas such as the Moosehorn National Wildlife Refuge.

These results should prove useful to the FWS when making air quality management decisions, including those related to the review of Prevention of Significant Deterioration (PSD) permits.

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Appendix – Vegetation at Moosehorn NWR

(As Furnished by the FWS)

Abies balsamea (balsam fir)
Acer pensylvanicum (striped maple)
Acer rubrum (red maple)
Acer saccharum (sugar maple)
Acer spicatum (mountain maple)
Achillea millefolium (common yarrow)
Actaea rubra (red baneberry)
Agropyron repens (Elytrigia repens var. repens)
Agrostis alba (Agrostis gigantea)
Alisma subcordatum (American water plantain)
Alnus crispa (Alnus viridis ssp. crispa)
Alnus rugosa (Alnus incana ssp. rugosa)
Alopecurus pratensis (meadow foxtail)
Amelanchier laevis (Allegheny serviceberry)
Anaphalis margaritacea (western pearly everlasting)
Andromeda glaucophylla (Andromeda polifolia var. glaucophylla)
Antennaria neodioica (Antennaria howellii ssp. neodioica)
Anthoxanthum odoratum (sweet vernalgrass)
Apocynum androsaemifolium (spreading dogbane)
Aquilegia vulgaris (European columbine)
Aralia hispida (bristly sarsaparilla)
Aralia nudicaulis (wild sarsaparilla)
Arctium minus (lesser burrdock)
Arisaema atrorubens (Arisaema triphyllum ssp. triphyllum)
Asclepias incarnata (swamp milkweed)
Asclepias syriaca (common milkweed)
Aster acuminatus (whorled wood aster)
Aster macrophyllus (bigleaf aster)
Aster radula (low rough aster)
Aster umbellatus (parasol aster)
Aster undulatus (waxyleaf aster)
Athyrium filix-femina (common ladyfern)
Barbarea vulgaris (garden yellowrocket)
Berberis thunbergii (Japanese barberry)
Betula papyrifera (paper birch)
Betula populifolia (gray birch)
Brassica juncea (India mustard)
Calamagrostis canadensis (bluejoint)
Capsella bursa-pastoris (shepherd's purse)
Carex crinita (fringed sedge)
Carex intumescens (greater bladder sedge)
Carex stricta (uptight sedge)

Carex trisperma (threeseeded sedge)
Carum carvi (caraway)
Cerastium vulgatum (Cerastium fontanum ssp. vulgare)
Chamaedaphne calyculata (leatherleaf)
Chelone glabra (white turtlehead)
Chimaphila umbellata (pipsissewa)
Chrysanthemum leucanthemum (Leucanthemum vulgare)
Circaea alpina (small enchanter's nightshade)
Cirsium arvense (Canadian thistle)
Cirsium discolor (field thistle)
Cirsium vulgare (bull thistle)
Clematis virginiana (devil's darning needles)
Clintonia borealis (yellow bluebeadlily)
Comptonia peregrina (sweet fern)
Coptis groenlandica (Coptis trifolia ssp. groenlandica)
Cornus alternifolia (alternateleaf dogwood)
Cornus canadensis (bunchberry dogwood)
Cornus stolonifera (Cornus sericea ssp. sericea)
Coronilla varia (purple crownvetch)
Corylus cornuta (beaked hazelnut)
Crassula aquatica (water pygmyweed)
Cycloloma atriplicifolium (winged pigweed)
Cypripedium acaule (pink lady's slipper)
Cypripedium calceolus ()
Dactylis glomerata (orchardgrass)
Dalibarda repens (robin runaway)
Danthonia spicata (poverty danthonia)
Dennstaedtia punctilobula (eastern hayscented fern)
Deschampsia flexuosa (wavy hairgrass)
Dianthus armeria (Deptford pink)
Diervilla lonicera (northern bush honeysuckle)
Distichlis spicata (inland saltgrass)
Dryopteris cristata (crested woodfern)
Dryopteris disjuncta (Gymnocarpium disjunctum)
Dryopteris marginalis (marginal woodfern)
Dryopteris noveboracensis (Thelypteris noveboracensis)
Dryopteris phegopteris (Phegopteris connectilis)
Dryopteris spinulosa (Dryopteris carthusiana)
Dryopteris thelypteris (Thelypteris palustris var. pubescens)
Dulichium arundinaceum (threeway sedge)
Epigaea repens (trailing arbutus)
Epilobium angustifolium (fireweed)
Equisetum arvense (field horsetail)
Equisetum fluviatile (water horsetail)
Equisetum hyemale (scouringrush horsetail)
Equisetum sylvaticum (woodland horsetail)

Erigeron annuus (eastern daisy fleabane)
Erigeron strigosus (prairie fleabane)
Eriocaulon septangulare (Eriocaulon aquaticum)
Eriophorum angustifolium (tall cottongrass)
Eriophorum spissum (Eriophorum vaginatum var. spissum)
Eupatoriadelphus purpureus (Eupatorium purpureum var. purpureum)
Eupatorium maculatum (spotted joepyeweed)
Euthamia graminifolia (flattop goldentop)
Fagus grandifolia (American beech)
Festuca capillata (Festuca filiformis)
Festuca elatior (Festuca pratensis)
Festuca rubra (red fescue)
Fragaria virginiana (Virginia strawberry)
Fraxinus americana (white ash)
Fraxinus pennsylvanica (green ash)
Galeopsis tetrahit (brittlestem hempnettle)
Galium mollugo (false baby's breath)
Galium palustre (common marsh bedstraw)
Galium triflorum (fragrant bedstraw)
Gaultheria hispidula (creeping snowberry)
Gaultheria procumbens (eastern teaberry)
Gaylussacia baccata (black huckleberry)
Gaylussacia dumosa (dwarf huckleberry)
Geranium bicknellii (Bicknell's cranesbill)
Glyceria canadensis (rattlesnake mannagrass)
Glyceria obtusa (Atlantic mannagrass)
Hamamelis virginiana (American witchhazel)
Hemerocallis fulva (orange daylily)
Hieracium aurantiacum (orange hawkweed)
Hieracium florentinum (Hieracium piloselloides)
Hieracium pilosella (mouseear hawkweed)
Hieracium pratense (Hieracium caespitosum)
Hordeum californicum (California barley)
Humulus lupulus (common hop)
Hypericum ellipticum (pale St. Johnswort)
Hypericum perforatum (common St. Johnswort)
Ilex verticillata (common winterberry)
Impatiens capensis (jewelweed)
Iris versicolor (harlequin blueflag)
Juniperus communis (common juniper)
Kalmia angustifolia (sheep laurel)
Kalmia polifolia (bog laurel)
Larix laricina (tamarack)
Ledum groenlandicum (bog Labradortea)
Lilium canadense (Canadian lily)
Linaria canadensis (Nuttallanthus canadensis)

Linaria vulgaris (butter and eggs)
Linnaea borealis (twinflower)
Lobelia cardinalis (cardinalflower)
Lobelia dortmanna (Dortmann's cardinalflower)
Lonicera canadensis (American fly honeysuckle)
Ludwigia palustris (marsh seedbox)
Luzula acuminata (hairy woodrush)
Luzula multiflora (common woodrush)
Lychnis alba (Silene latifolia ssp. alba)
Lycopodium annotinum (stiff clubmoss)
Lycopodium clavatum (running clubmoss)
Lycopodium complanatum (groundcedar)
Lycopodium lucidulum (Huperzia lucidula)
Lycopodium obscurum (rare clubmoss)
Lycopodium tristachyum (deeproot clubmoss)
Lycopus americanus (American waterhorehound)
Lycopus uniflorus (northern bugleweed)
Lycopus virginicus (Virginia waterhorehound)
Lysimachia terrestris (earth loosestrife)
Maianthemum canadense (Canada beadruby)
Matricaria matricarioides (Matricaria discoidea)
Medeola virginiana (Indian cucumberroot)
Medicago sativa (alfalfa)
Melampyrum lineare (narrowleaf cowwheat)
Melilotus alba (white sweetclover)
Melilotus officinalis (yellow sweetclover)
Mentha arvensis (Mentha canadensis)
Mimulus ringens (ringen monkeyflower)
Mitchella repens (partridgeberry)
Moneses uniflora (single delight)
Myrica gale (sweetgale)
Myriophyllum exalbescens (Myriophyllum sibiricum)
Nuphar variegata (Nuphar lutea ssp. variegata)
Nymphaea odorata (American white waterlily)
Nymphoides cordata (little floatingheart)
Odontites serotinus (Odontites vernus ssp. serotinus)
Oenothera biennis (common eveningprimrose)
Oenothera fruticosa (narrowleaf eveningprimrose)
Onoclea sensibilis (sensitive fern)
Oryzopsis asperifolia (roughleaf ricegrass)
Osmunda cinnamomea (cinnamon fern)
Osmunda claytoniana (interrupted fern)
Osmunda regalis (royal fern)
Oxalis europaea (Oxalis stricta)
Oxalis montana (mountain woodsorrel)
Oxalis stricta (common yellow oxalis)

Phalaris arundinacea (reed canarygrass)
Phleum pratense (timothy)
Picea abies (Norway spruce)
Picea glauca (white spruce)
Picea mariana (black spruce)
Picea rubens (red spruce)
Pinus resinosa (red pine)
Pinus strobus (eastern white pine)
Plantago major (common plantain)
Pogonia ophioglossoides (snakemouth orchid)
Polygonatum pubescens (hairy Solomon's seal)
Polygonum amphibium (water knotweed)
Polygonum careyi (Carey's smartweed)
Polygonum cilinode (fringed black bindweed)
Polygonum lapathifolium (curlytop knotweed)
Polygonum pensylvanicum (Pennsylvania smartweed)
Polygonum punctatum (dotted smartweed)
Polypodium virginianum (rock polypody)
Polystichum acrostichoides (Christmas fern)
Pontederia cordata (pickerelweed)
Populus balsamifera (balsam poplar)
Populus grandidentata (bigtooth aspen)
Populus tremuloides (quaking aspen)
Potamogeton epihydrus (ribbonleaf pondweed)
Potamogeton natans (floating pondweed)
Potamogeton pectinatus (sago pondweed)
Potamogeton zosteriformis (flatstem pondweed)
Potentilla anserina (Argentina anserina)
Potentilla argentea (silver cinquefoil)
Potentilla norvegica (Norwegian cinquefoil)
Potentilla recta (sulphur cinquefoil)
Potentilla simplex (common cinquefoil)
Prunella vulgaris (common selfheal)
Prunus pensylvanica (pin cherry)
Prunus pumila var. besseyi (western sandcherry)
Prunus serotina (black cherry)
Prunus virginiana (common chokecherry)
Pteridium aquilinum (western brackenfern)
Pyrola elliptica (waxflower shinleaf)
Pyrola rotundifolia (Pyrola americana)
Pyrus americana (Sorbus americana)
Pyrus floribunda (Aronia X prunifolia)
Pyrus malus (Malus sylvestris)
Pyrus melanocarpa (Aronia melanocarpa)
Quercus rubra (northern red oak)
Ranunculus acris (tall buttercup)

Rhinanthus crista-galli (Rhinanthus minor ssp. minor)
Rhododendron canadense (rhodora)
Rhus radicans (Toxicodendron radicans ssp. radicans)
Rhus typhina (Rhus hirta)
Ribes glandulosum (skunk currant)
Ribes hirtellum (hairystem gooseberry)
Rubus allegheniensis (Allegheny blackberry)
Rubus hispidus (bristly dewberry)
Rubus idaeus (American red raspberry)
Rubus pubescens (dwarf red blackberry)
Rudbeckia serotina (Rudbeckia hirta var. pulcherrima)
Rumex acetosella (common sheep sorrel)
Ruppia maritima (widgeongrass)
Sagittaria latifolia (broadleaf arrowhead)
Salicornia europaea (Salicornia maritima)
Salix bebbiana (Bebb willow)
Salix gracilis (Salix petiolaris)
Sambucus canadensis (American elder)
Sarracenia purpurea (purple pitcherplant)
Scirpus atrovirens (green bulrush)
Scirpus cyperinus (woolgrass)
Scirpus pedicellatus (stalked bulrush)
Scirpus rubrotinctus (Scirpus microcarpus)
Scutellaria epilobiifolia (Scutellaria galericulata)
Scutellaria lateriflora (blue skullcap)
Sedum purpureum (Sedum telephium ssp. telephium)
Senecio aureus (golden ragwort)
Senecio vulgaris (common groundsel)
Silene antirrhina (sleepy silene)
Silene cucubalus (Silene vulgaris)
Sisyrinchium montanum (mountain blueeyed grass)
Sium suave (hemlock waterparsnip)
Smilacina racemosa (Maianthemum racemosum ssp. racemosum)
Smilacina trifolia (Maianthemum trifolium)
Solanum dulcamara (climbing nightshade)
Solidago graminifolia (Euthamia graminifolia var. graminifolia)
Spiraea latifolia (Spiraea alba var. latifolia)
Spiraea tomentosa (steeplebush)
Stellaria graminea (grasslike starwort)
Taraxacum officinale (common dandelion)
Taxilejeunea (taxilejeunea)
Thalictrum polygamum (Thalictrum pubescens)
Thelypteris thelypterioides (Thelypteris noveboracensis)
Thuja occidentalis (eastern arborvitae)
Tragopogon pratensis (meadow salsify)
Trientalis borealis (American starflower)

Trifolium agrarium (Trifolium aureum)
Trifolium arvense (rabbitfoot clover)
Trifolium hybridum (alsike clover)
Trifolium pratense (red clover)
Trifolium repens (white clover)
Tsuga canadensis (eastern hemlock)
Typha angustifolia (narrowleaf cattail)
Typha latifolia (broadleaf cattail)
Utricularia cornuta (horned bladderwort)
Utricularia purpurea (eastern purple bladderwort)
Utricularia vulgaris (Utricularia macrorhiza)
Uvularia sessilifolia (sessileleaf bellwort)
Vaccinium angustifolium (lowbush blueberry)
Vaccinium corymbosum (highbush blueberry)
Vaccinium macrocarpon (cranberry)
Vaccinium myrtilloides (velvetleaf huckleberry)
Vaccinium oxycoccos (small cranberry)
Vaccinium vitis-idaea (lingonberry)
Valeriana uliginosa (mountain valerian)
Vallisneria americana (American eelgrass)
Verbascum thapsus (common mullein)
Veronica officinalis (common gypsyweed)
Veronica scutellata (skullcap speedwell)
Veronica serpyllifolia (thymeleaf speedwell)
Viburnum cassinoides (Viburnum nudum var. cassinoides)
Viburnum lentago (nannyberry)
Viburnum recognitum (Viburnum dentatum var. lucidum)
Viburnum trilobum (Viburnum opulus var. americanum)
Vicia cracca (bird vetch)
Vicia sepium (bush vetch)
Viola adunca (hookedspur violet)
Viola cucullata (marsh blue violet)
Viola pallens (Viola macloskeyi ssp. pallens)
Viola septentrionalis (northern blue violet)